SS3011

SS 3011
Space Technology and Applications

• Midterm Exam

Due Monday, November 19
Start of Class

Take Home, Open Notes, Open Book, Open Web ....

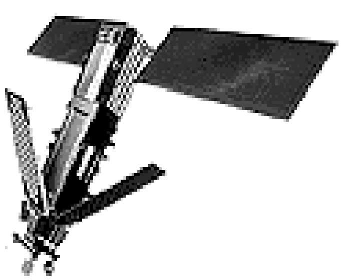
Students Work Individually

Show All Work and Units on Every Calculation

Naval Postgraduate School
Monterey, California

SS3011

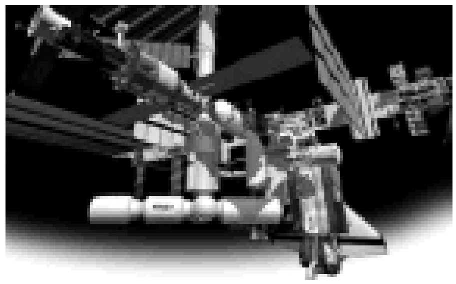
Iridium Constellation First Global Satellite Network for Telecommunication.



- **Orbit *Altitude*, 780 km**
- **Orbit inclination, 86.4°**
- **Orbit eccentricity, 0.0**
- **Weight, 689 kg**
- **Expected Lifetime (per satellite) 7-9 years**

Naval Postgraduate School
Monterey, California

OK, each satellite costs over 80 Million ... and 7-9 years isn't very many Phone Calls



.... so we want to design a "rescue mission" that brings the satellite back to the Space Station ... so it can be returned by the Shuttle for refurbishment

.... Shuttle usually returns empty anyhow

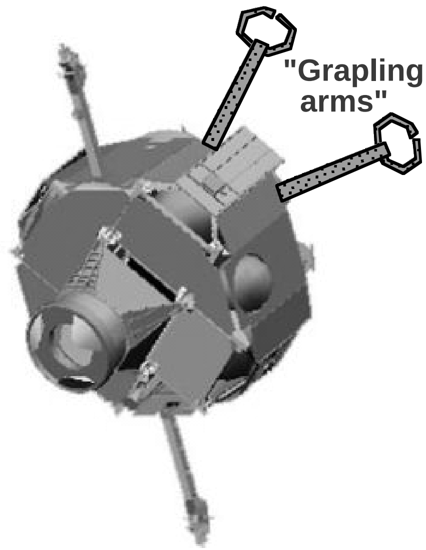
Please Note

- **This Mission *May* or *May NOT* Be Feasible**

... you have to decide

The "Rescue Ship"

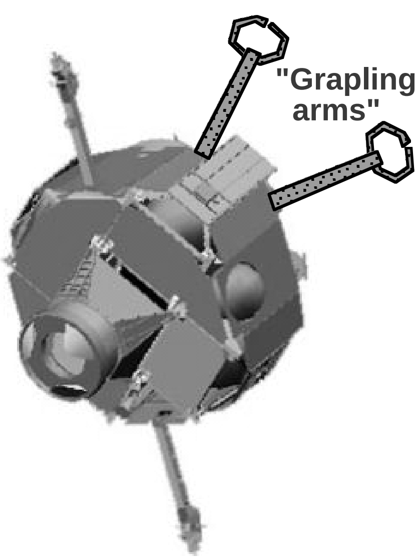
• Modified version of the 'Interim Control Module"
(Designed as a backup for the Russian Zarya Module)



Russian Zarya Propulsion Module

ICM V2.1

Rescue Ship (cont'd)



- **Serviced and Launched from International Space Station (ISS)**
- **ISS Orbit parameters**

  Altitide, 407 km
  Inclination, 51.6°
  Eccentricity, 0.0

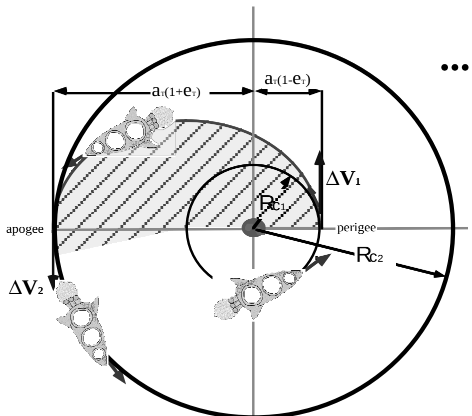
- **ICM Characteristics**

  Propellant MMH (Monomethyl Hydrazine)
  Isp -- 325 sec (upgraded engine)
  Dry Weight, 8,600 kg

The Design Process

1) Design the Hohmann Transfer Orbit required to move the ICM from the ISS to the Iridium Orbit Altitude

i.e. ... calculate a_T, e_T for the transfer orbit



... assume R_{earth} = 6371 km

Hint 1: R_{min} ... transfer orbit ... = Radius ... ISS Orbit ...

SS3011

Time of Flight

2) How Long Does it take the ICM to reach the Iridium orbit

- **Hint 2: Kepler's Third law**

$$T_T \Rightarrow \frac{2\pi\left[a_{Transfer}\right]^{3/2}}{\sqrt{\mu}}$$

$$(TOF)_T = \frac{T_T}{2}$$

Naval Postgraduate School
Monterey, California

Enter Transfer Orbit

3) Compute ΔV1 Required to Insert ICM into Transfer Orbit

- **Hint 3:**

$$\frac{\Delta V_1}{\sqrt{\frac{\mu}{R_{c_1}}}} = \sqrt{2\left[1 - \frac{1}{\left[\frac{R_{c_2}}{R_{c_1}} + 1\right]}\right]} - 1$$

SS3011

Enter Iridium Orbit

4) Compute ΔV2 Required to Insert ICM into a Circular orbit at the altitude of the Iridium Orbit

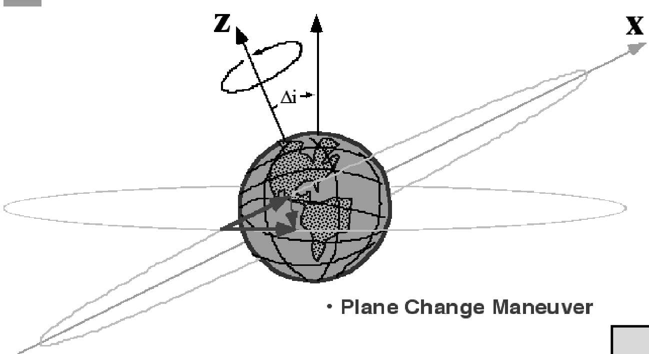
- **Hint 4:**

$$\frac{\Delta V_2}{\sqrt{\frac{\mu}{R_{c_1}}}} = \left[\sqrt{\frac{1}{\frac{R_{c_2}}{R_{c_1}}}} - \sqrt{2\left[\frac{1}{\left[\frac{R_{c_2}}{R_{c_1}}\right]} - \frac{1}{\left[\frac{R_{c_2}}{R_{c_1}} + 1\right]}\right]}\right]$$

Naval Postgraduate School
Monterey, California

Change Orbital Planes

5) Once inserted into the orbital altitude of the Iridium Calculate ΔV required for ICM to Perform a *simple plane change* to move from the orbital plane of the ISS to Iridium Orbital plane



• Plane Change Maneuver

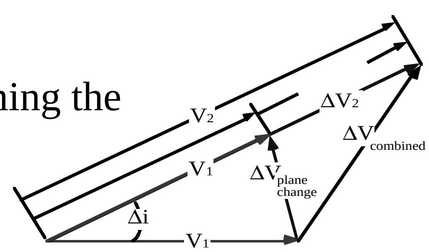
• **Hint 5**

$$\left|\Delta V\right|_{\substack{\text{simple}\\\text{plane}\\\text{change}}} = 2\sin\left[\frac{\Delta i}{2}\right] V_{initial}$$

Combined Plane Change

6) Compute the DV required to Do the Iridium Orbit insertion and Plane Change at the same time

Compare the results to performing the maneuvers separately



Hint 6:

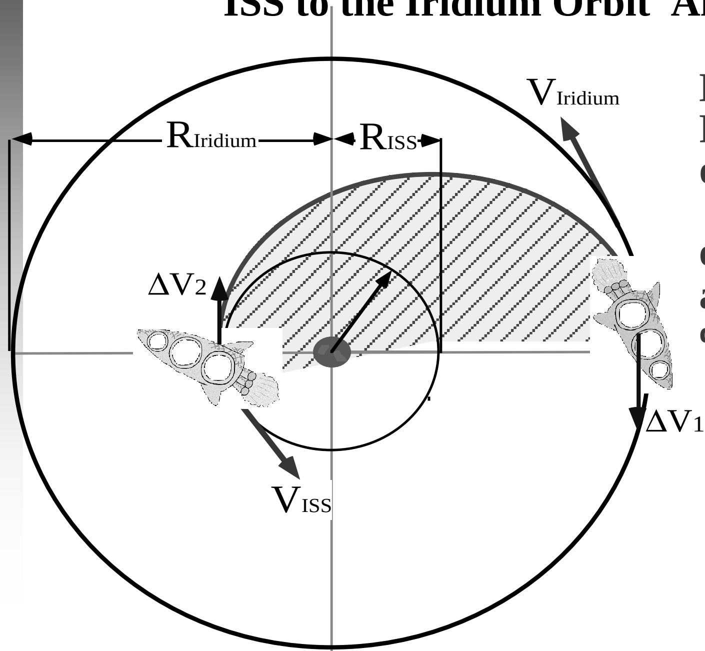
$$\left|\Delta V\right|_{combined} = \sqrt{\left|V_2\right|^2 + \left|V_1\right|^2 - 2\left|V_2\right|\left|V_1\right|\cos\left[\Delta i\right]}$$

$V_2 =$ Iridium orbit speed

$V_1 =$ Velocity at perigee of transfer orbit

The Return Trip

7) Design the Hohmann Transfer Orbit and ΔV's required to return the ICM from the ISS to the Iridium Orbit Altitude



Hint 7:
Return trip is the reverse of the Outward Bound trip

excepts rocket burns (ΔV's) are *retrograde* **(i.e. opposite direction from outward trip)**

(Include Plane Change in Calculations, *use minimum value)*

Fuel Budgeting

- **Calculate the minimum amounts of fuel to be consumed for each burn and the minimum total fuel which must be budgeted for the round trip**

- **Hint 8: Start with the final burn and work backward**
  Don't forget that Both vehicles are making return trip

$$M_{propellant} = \left[M_{dry} + M_{payload}\right]\left[e^{\left[\frac{\Delta V_{burn}}{g_0 \, I_{sp}}\right]} - 1\right]$$